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FINAL REPORT: NAGW-1084

"Structural and Volcanic Evolution of Martian and Terrestrial Shield Volcanoes"

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1. REVIEW OF PROJECT GOALS

A basaltic volcano is much more than merely being an accumulation of lava flows and pyroclastic rocks, and its morphology is conditioned by many parameters additional to the rheology of its lava flows. This truism expresses the fact that a basaltic volcano is a complex system of intrusives as well as effusive rock bodies. The external morphology of a major basaltic volcano, either on Mars or on the Earth, thus depends at least as much on the internal plumbing system of the volcano as on the flow behavior of its lava flows. Not only does the shape (morphology) of the volcano depend on the balance between internal and external forces, but also for Mars the degree of interaction between intrusives and regolith volatiles will be influenced by the internal structure of the volcano. Our three-year project was therefore designed to further our understanding of terrestrial volcanoes, and to translate that knowledge into the interpretation of similar landforms on Mars.

Before we started our investigation, earlier studies had shown that melt water release from areas peripheral to major volcanic constructs may have been a common phenomenon, and our mapping of channels within the Tharsis region appears to confirm this view. In addition, such volcano/ground ice interactions may also have influenced the distribution of explosive volcanism on Mars. Thus, this project attempted to investigate the relative roles of extrusive and intrusive activity on Mars using terrestrial analogs and photogeologic mapping of Viking Orbiter images, and to identify the places where consequent release of melt water took place at the surface around martian volcanoes.

The objectives of our project were to perform a structural analysis of basaltic shield volcanoes on the Earth, thereby enabling the mechanism(s) of volcano growth, intrusion and subsidence of martian volcanoes to be predicted. Information on the mechanism(s) of dike intrusion and summit collapse for terrestrial volcanoes is to be used to help interpret the volcanic and tectonic evolution of martian shields volcanoes, and the possible consequences of volcano/ground ice interactions, as derived from photogeologic mapping and numerical modeling.

2. ACCOMPLISHMENTS

Our accomplishments included the publication of the first comprehensive analysis of explosive and effusive volcanism on the volcano Alba Patera, the field investigation of dike swarms on Hawaiian and Galapagos volcanoes, the identification of recent water release peripheral to large volcanoes in the Tharsis region of Mars, and the quantitative analysis of the deformation history of the summit of Olympus Mons volcano, Mars. Because of our comparisons between martian and terrestrial volcanoes, we feel that the Mars community is now more aware of the diversity of eruption styles of martian volcanoes, and has also come to consider the internal structure of volcanoes as an important factor in the formation of landforms that are visible from orbit.

We published a new model for the evolution of Alba Patera, that proposes that polygenic activity (early explosive volcanism, late-stage effusive activity) characterized this volcano and may be responsible for the unique morphology of Alba. We believe that interactions between the ascending magma and ground ice could be the cause of this change in activity, and so have published a photogeologic analysis of the Tharsis region which describes further evidence of late-stage melt water release.

Collaborative work with Maria Zuber (at the NASA/Goddard SFC) was undertaken on the

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finite element modeling and topographic analysis of the Olympus Mons caldera. The floor of this caldera appears to have deformed during subsidence of a cooling lava lake, and we are attempting to model the effects of magma withdrawal from a magma chamber on summit collapse. Visits to the active lava lake of Kilauea have also provided some geomorphic insights into the possible origin of some of the floor features within the martian caldera. We constructed a new topographic model for the summit of Olympus Mons, because we feel that the asymmetric relief of the rim provides important information on the effect of intrusions (dikes) close to the summit, and we are using our earlier measurements of Hawaiian dike swarms as analogs.

Our work on the Hawaiian volcanoes produced new insights into the manner by which magma is injected along dikes and the progressive spatial migration of summit calderas, and this last year we have published two papers on this subject. We also developed a more complete method for studying the magnetic properties of dikes so that these flow directions can be more efficiently documented. Our field expedition to the Galapagos Islands provided many new insights to the seven active shield volcanoes in the western portion of this archipelago, and we used this investigation to refine our ideas of the internal structure of terrestrial and martian volcanoes.

We should also note that because of limitations in funding (we were awarded only half the amount that we originally included in our proposal), some of the original objectives of our proposed research could not be met. Specifically, we were not able to fund field work to the Isle of Skye (Scotland) or to Reunion Island (Indian Ocean), and so we were not able to carry out the analysis of dike swarms at different levels beneath the original volcano summit. To a certain extent, our investigation plan was modified to reduce the field costs, and included visits to some of the more eroded Hawaiian volcanoes on Molokai and Kauai. Our field trip to the Galapagos Islands was also helpful in this regard.

In summary, as a result of our funding under NASA Grant NAGW-1084 we published (or have in press/in review) 9 papers in the open literature, presented 9 oral presentations, published 12 extended abstracts, given 7 oral presentations, and hosted two topical conferences on aspects of martian volcanism because of the supported provided to us by the MEVTV Program. We ran two highly successful workshops in Hawaii (June 1988) and San Diego (January 1990), where the physical volcanology and petrology of Mars was discussed by ~40 planetary and terrestrial scientists. A special conference proceedings (Lunar and Planetary Institute Technical Report 90-04) was published following the San Diego meeting. A complete list of the publications and presentations derived from support from this project is given in the attached bibliography.

In addition to these published works, we are delighted that support for our investigation enabled two University of Hawaii graduate students to gain their Ph.D. degrees. Dr. Scott Rowland, after two-year departure from Hawaii (when he worked for the U.S. Geological Survey in Menlo Park, CA, and a private geological research firm) is now a post-doc in Hawaii working on the analysis of active volcanoes on Earth using satellites. Dr. Michael Knight is now working for a geological exploration firm in Honolulu, Hawaii. Both Scott and Mike thank NASA for their graduate support.

Pete Mouginis-Mark 9/30/90

Peter J. Mouginis-Mark
Principal Investigator

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